Baseline Indoor Air Quality Field Study in Occupied New U.S. Homes: Cold and Marine Climate Zones

Pacific Northwest National Laboratory
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Images from epa.gov and medlineplus.gov
Project Summary

**Timeline:**
Start date: 10/1/2017
Planned end date: 3/30/2020

**Key Milestones**
1. Obtain IRB approval: 3/31/2018
2. Go/No-Go: Complete 8 homes, 12/31/2018
3. Complete 22 homes, 3/31/2019

**Budget:**

**Total Project $ to Date:**
- DOE: $528k
- Cost Share: $25k +58k (just contracted)

**Total Project $:**
- DOE: $795k
- Cost Share: $105k

<table>
<thead>
<tr>
<th>Key Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmus</td>
</tr>
<tr>
<td>WSU</td>
</tr>
<tr>
<td>Panasonic</td>
</tr>
<tr>
<td>NEEA</td>
</tr>
<tr>
<td>SWEEP</td>
</tr>
</tbody>
</table>

**Project Outcome:**
1) Improve understanding of potential health risks in new homes as industry works to achieve MYPP goal of 60% lower energy use.
2) Determination of how much the air flow, and specifically, correctly designed mechanical ventilation, affects the indoor air quality (IAQ) in new homes in the cold and marine climate zones.
Baseline IAQ Field Study in Occupied New U.S. Homes: Cold and Marine Climates

Team Lead: Pacific Northwest National Laboratory

Cheryn Metzger
Senior Engineer
Project Manager/Co-PI

Dr. Jian Zhang
Senior Engineer
Co-PI

Chrissi Antonopoulos
Analyst

Michael Baechler
Senior Scientist

Cadmus, WSU, and Ecotope

Mitt Jones/Paul Norton
Lead Field Technicians

Mike Lubliner and Dave Baylon
QA/QC
Voting Members ASHRAE 62.2 Committee

Unique Team Traits:
Residential and indoor air quality and field data collection experts, all team members playing to their strengths for highest efficiency.
Challenge

• Air tightness reduces energy use for thermal conditioning but can increase risks of some IAQ problems.

• Adequate ventilation is necessary – though not always sufficient - for acceptable IAQ.
  – ASHRAE 62.2 sets requirements for ventilation equipment and minimum outdoor air rates in homes.
  – Several states and many home performance programs include mechanical ventilation requirements.

• Limited data indicate deficiencies:
  – many new homes lack general ventilation or kitchen exhaust
  – installed systems commonly don’t meet standards
  – Installed systems often not used as intended
Approach

- Conduct field study in varied US climate zones.
- Recruit homes that represent diversity of construction styles and mechanical system designs in each climate zone.
- Visual characterization and performance measurements on site.
- Survey of occupants about activities and perceptions.
- Measurements of pollutants and equipment use over 1 week with windows closed (seasonally appropriate).
- Analyze data to quantify concentrations, emission rates, use and effectiveness of MV, etc.

Targets
- 32 homes/zone
- 16 w/ mech vent
- 8 get 2-week test
Tightener US homes will use 3 Quads less source energy per year\(^1\)

<table>
<thead>
<tr>
<th>Source Energy Savings (Quads)</th>
<th>Passive House Equivalent:</th>
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</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Air tightness;</td>
</tr>
<tr>
<td></td>
<td>Smart ventilation;</td>
</tr>
<tr>
<td></td>
<td>Sensors and air cleaning;</td>
</tr>
<tr>
<td></td>
<td>Source control</td>
</tr>
<tr>
<td>1.4</td>
<td>Advanced air sealing with 62.2 ventilation. Some air sealing and IAQ R&amp;D needed</td>
</tr>
<tr>
<td>1.3</td>
<td>Standard air sealing with 62.2 ventilation</td>
</tr>
</tbody>
</table>

California study found acceptable IAQ in newish homes with MV

<table>
<thead>
<tr>
<th>Mean indoor concentration</th>
<th>CA homes pre-MV</th>
<th>CA homes with MV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde</td>
<td>36.3 ppb</td>
<td>19.8 ppb</td>
</tr>
<tr>
<td>PM(_{2.5})</td>
<td>13.3 (\mu g/m^3)</td>
<td>8.3 (\mu g/m^3)</td>
</tr>
<tr>
<td>NO(_2)</td>
<td>5.4 ppb</td>
<td>6.1 ppb</td>
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</tbody>
</table>

Since 2012, IECC requires dwelling unit mechanical ventilation (DUMV).

Kitchen exhaust still not required.

Some states requiring DUMV only for tightest homes, e.g. <3 ACH50.

Field data will inform future revisions to industry standards.
PNNL Progress

• Designed recruitment strategy around trying to obtain calculated variation in homes
• Calculated percentages using Residential Energy Consumption Survey (RECS)
  – House size
  – Basement or not
  – Occupancy
  – HVAC types
  – Natural gas use or not
  – Code or above-code
• Mechanical Ventilation or not
Focused on getting the homes with mechanical ventilation (harder to find) first. Once enough homes with mechanical ventilation have been recruited, code-built homes can be recruited by purchasing addresses through real estate sites.

Portland, OR, Recruitment
- Using database of homes certified by a local non-profit organization named Earth Advantage
  - All homes should meet ASHRAE 62.2 2010
- Focused on homes close to the Portland area

Boulder, CO, Recruitment
- Leverage Thrive as a builder partner (above code)
  - All homes should meet ASHRAE 62.2 2010
- Purchased database of new homes by zip code (code-built)
- Focused on homes within 30-minute drive
PNNL Progress - Portland

- Some infill, some new subdivisions
# PNNL Progress – 8 Homes in Portland

<table>
<thead>
<tr>
<th>Home ID</th>
<th>Yr. Built</th>
<th>Sq. Ft.</th>
<th># of People</th>
<th>Whole House Vent?</th>
<th>FRM In (ppb)</th>
<th>FRM Out (ppb)</th>
<th>NO2 In (ppb)</th>
<th>NO2 Out (ppb)</th>
<th>PM In (ug/m3)</th>
<th>PM Out (ug/m3)</th>
<th>Radon (pCi/L)</th>
<th>ACH50</th>
<th>DuctLeak (cfm)</th>
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<tbody>
<tr>
<td>Threshold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7/80*</td>
<td>7/80*</td>
<td>53</td>
<td>53</td>
<td>12</td>
<td>12</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>2016</td>
<td>2000</td>
<td>3</td>
<td>S</td>
<td>58</td>
<td>9</td>
<td>21</td>
<td>12</td>
<td>18</td>
<td>4</td>
<td>1.5</td>
<td>2.6</td>
<td>67</td>
</tr>
<tr>
<td>202</td>
<td>2015</td>
<td>1956</td>
<td>2</td>
<td>EX</td>
<td>15</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>10</td>
<td>29</td>
<td>1.5</td>
<td>3.9</td>
<td>36</td>
</tr>
<tr>
<td>203</td>
<td>2016</td>
<td>2546</td>
<td>2</td>
<td>None</td>
<td>43</td>
<td>3</td>
<td>6</td>
<td>8</td>
<td>51</td>
<td>45</td>
<td>0.9</td>
<td>4.8</td>
<td>155</td>
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<tr>
<td>204</td>
<td>2016</td>
<td>3010</td>
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<td>S</td>
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<td>3</td>
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<td>6</td>
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<td>7</td>
<td>0.5</td>
<td>3.9</td>
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<td>206</td>
<td>2017</td>
<td>2856</td>
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<td>S</td>
<td>32</td>
<td>3</td>
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<td>207</td>
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<td>8</td>
<td>LP</td>
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<td>2017</td>
<td>1576</td>
<td>1</td>
<td>S</td>
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<td>2</td>
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<td>17</td>
<td>28</td>
<td>1.5</td>
<td>3.2</td>
<td>17</td>
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</tbody>
</table>

Red text indicates kitchen exhaust is non-compliant.

S= Supply  EX= Exhaust  NP=Not performed due to wildfire  TH=Too high to measure, likely due to open damper  CP = Lab Processing
PNNL Progress - Portland

- 6 of the 8 Portland Homes had supply ventilation, all but one inaccessible to measure

- Not enough space for accurate velocity traverse

- Not safe to measure
Preliminary Results

- U.S. Annual Air Quality Standard for Ambient Outdoor Air = 12 µg/m$^3$
- 2 homes tested during the wildfire “season,” with outdoor PM2.5 average above 25 µg/m$^3$. One home does not make a trend, but the home with continuous exhaust ventilation (and ACH50 of 3.9) had average indoor PM2.5 of 10 µg/m$^3$, while home with no mechanical ventilation (and ACH50 4.8) had average indoor PM2.5 of 50 µg/m$^3$. 

Photo: weather.gov
PNNL Progress – Boulder Area

- 14 homes complete
- Some infill, some new developments
- 5 2-week homes
PNNL Progress – Boulder Area

- Mostly exhaust systems, some ERV
- No challenges measuring airflow

ERV intake within reach!
Stakeholder Engagement

• Advisory Committee
  – Meets approximately bi-annually
  – Specific questions to specific entities more frequently
Remaining Project Work

- Finish data collection in Boulder, CO
- Send equipment out for calibration
- Send equipment back to Portland, OR
- Finish data collection in Portland, OR
- Institutional Review Board (IRB) approval caused ~ 2 month delay to field work early in project
- Remaining data collection likely to continue into middle of FY20
- Analyze data for each climate region
- Report results to ASHRAE 62.2 committee
Thank You

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Cheryn.Metzger@pnnl.gov
REFERENCE SLIDES
Project Budget

Project Budget: See below
Variances: No variances
Cost to Date: 66% spent to date
Additional Funding: None

<table>
<thead>
<tr>
<th>Budget History</th>
<th>FY 2017-2018 (past)</th>
<th>FY 2019 (current)</th>
<th>FY 2020 (Future)</th>
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## PNNL Project Plan and Schedule

### Milestone Summary Table

<table>
<thead>
<tr>
<th>Recipient Name:</th>
<th>Baseline Indoor Air Quality (IAQ) Field Study in Occupied New U.S. Homes: Cold and Marine Climates</th>
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<tbody>
<tr>
<td><strong>Task Number</strong></td>
<td><strong>Task or Subtask</strong></td>
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<tr>
<td>1.0</td>
<td>Development and Approval of Study Protocol</td>
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<tr>
<td>2.0</td>
<td>Field Test Preparation</td>
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<tr>
<td>3.0</td>
<td>Field Data Collection and Monitoring</td>
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<td>Go/No-Go Decision Point</td>
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### Project Plan and Schedule

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<table>
<thead>
<tr>
<th>Recipient Name:</th>
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<table>
<thead>
<tr>
<th>Task Number</th>
<th>Task or Subtask (if applicable) Title</th>
<th>Milestone Type (Milestone or Go/No-Go Decision Point)</th>
<th>Milestone Number* (Go/No-Go Decision Point Number)</th>
<th>Milestone Description (Go/No-Go Decision Criteria)</th>
<th>Milestone Verification Process (What, How, Who, Where)</th>
<th>Anticipated Date (Months from Start of the Project)</th>
<th>Anticipated Quarter (Quarters from Start of the Project)</th>
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<tbody>
<tr>
<td>3.0</td>
<td>Field Data Collection and Monitoring (continued)</td>
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<td>Milestone</td>
<td>3.2</td>
<td>Complete assessments in 20 additional homes (total of 28), QA review and upload data.</td>
<td>Data uploaded to central repository.</td>
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<td>5.0</td>
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<td>Submit Draft Technical Report</td>
<td>Draft report detailing approach, analysis, and results.</td>
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<td>Present results</td>
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<td>Submit Final Technical Report</td>
<td>Final report detailing approach, analysis, and results.</td>
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<td>10</td>
<td></td>
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